Indian Head Lentil as a Green Manure Substitute for Summerfallow

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Abstract
Indian Head lentil, a small black seeded cultivar, can fix substantial amounts of nitrogen while providing a dense ground cover. It has been promoted as a green manure alternative to conventional summerfallow. To evaluate the impact that use of this crop as a green manure might have on grain yield of succeeding crops, two studies were initiated at the Scott Experimental Farm. In the first study, incorporating green manure at the bud or at full bloom stages of growth were compared with conventional summerfallow, or where field pea, lentil or wheat were grown as grain. In a second study several methods of managing the green manure crop were evaluated including herbicide desiccation, incorporation and use of crop trap strips to trap snow and replenish soil moisture reserves.

Introduction

Summerfallow is the practice of leaving fields free of crop and controlling weed growth during one growing season. Advantages of this practice are improved soil moisture levels, increased amounts of available soil nutrients particularly nitrogen, enhanced weed control and in some cases reduced disease incidence. However there are a number of detrimental effects of this practice including accellerated loss of soil organic matter, increased soil erosion and excess moisture contributing to salinity. At the Scott Experimental Farm a number of soil conserving practices including extended cropping and alternate methods of summerfallowing are being evaluated, one such method is the use of legume green manures.

Legume green manures offer several advantages over conventional summerfallow practices. They can add substantial amounts of organic matter to the soil at a period of time where conventional summerfallow adds little if any. Properly inoculated legumes have the capacity to fix atmospheric nitrogen and make it available to succeeding crops as residues decompose. While the crop is growing it provides soil cover to protect against erosion. Moisture use by the crop reduces the amount percolating through the soil and contributing to salinity or leaching of nutrients from the rooting zone.

Despite these advantages, green manuring is not a widely accepted practice on the Brown and Dark Brown soils where summerfallow is most extensively practiced. A statistics Canada farm energy survey in 1982 estimated that less than 2% of farmers in the Dark Brown soil zone of Saskatchewan practiced green manuring and 0% in the Brown soil zone. In a survey of Agricultural Representatives (Kirkland and Brandt, 1984) it was estimated that green manuring was practiced on over 3% of summerfallow acres of the Dark Brown soil zone of Saskatchewan.

A number of factors have been cited as reasons for not utilizing green manure crops. A major factor has been the high cost of seed for green manure crops but other factors such as poor establishment and weak competition with weeds also deter their use. Ultimately green manures must be evaluated for their impact on production of succeeding crops. In many cases stored soil moisture is reduced and weed control problems are aggravated leading to reduced grain yields.

In the past, perennial or biennial legumes were most commonly used for green manuring. More recently annual legumes have been evaluated as a possible means of overcoming some of these disadvantages (Biederbeck and Slinkard 1988). The most promising of these is the small black seeded Indian Head lentil cultivar. Seeding rates and seed costs are relatively low and it has been demonstrated that the value of nitrogen fixed by the crop exceeds the cost of seed (Slinkard and Beiderbeck 1987). Being an annual crop, rooting depth is shallower than for alfalfa or sweetclover thereby reducing moisture use. The crop establishes rapidly and it is relatively easy to obtain a vigorous stand. Because this crop appeared to have the greatest potential for use as a annual legume green manure it was selected for use in these studies.

Two studies were initiated to evaluate the use of annual legumes as alternatives to conventional tillage summerfallow practices. The first study, initiated in 1984 was designed to compare the use of Indian Head lentil as a green manure crop with conventional summerfallow practices as well as with stubble cropping with several crops. The primary objective of this study was to evaluate the effect of these treatments on yield of succeeding crops, but also to develop a base of data on the effect of green manuring on such factors as levels of available soil moisture and nutrients, quantities of organic matter and nitrogen returned to the soil and resulting weed control problems compared with conventional summerfallow and extended cropping practices

A second study was initiated in 1987 to evaluate several methods of managing a lentil green manure crop in an attempt to reduce the impact of moisture use by the green manure crop on yields of the succeeding crop. Several practices were evaluated to limit soil moisture use by the green manure crop and/or recover moisture used by employing snow trapping techniques.

<u>Materials and Methods</u>

In the study initiated in 1984 treatments consisted of growing lentil as a green manure crop and incorporating early at the bud stage or later at full bloom. For comparison, a conventional summerfallow treatment was included along with treatments where pea and lentil were grown as grain and treatments where wheat was grown with and without fertilizer nitrogen at 40 kg/ha. For all crops grown as grain, phosphate fertilizer was seed placed at 25 kg/ha. The green manure crops were not fertilized.

At time of incorporation of the green manure crops, all above ground material was collected from 2 meter square areas of each green manure plot. Roots from the same areas were excavated, soil removed and both the roots and above ground material oven dried to provide an estimate of the amount of dry matter returned to the soil. These same samples were analysed for their N content to provide an estimate of the amount of nitrogen returned to the soil.

The following year, the entire plot area was seeded to wheat with 30 kg/ha of seed placed phosphate. The only treatment to receive N fertilizer was the treatment that had wheat fertilized with N the precedings year. For this treatment N at 40 kg/ha was banded prior to seeding. Yield, seed weight, volume weight and protein content of the succeeding wheat crop were determined. The third year, plots were split into 3 sub-plots with nitrogen applied at 0, 40 or 80 kg/ha. The entire plot area was sown to barley with 30 kg/ha of phosphate seed placed. Barley yields were determined at maturity.

In the second green manure study initiated in 1987, eight different management treatments were compared. The treatments were as follows:

1. Incorporate at bud stage
2. Incorporate at full bloom stage
3. Desiccate at full bloom stage using Reglone
4. Apply 2,4-D at full bloom stage
5. Incorporate at full bloom and plant mustard in rows to act as a snow trap
6. Incorporate at full bloom but leave strips standing to trap snow
7. Grown to maturity and harvest as seed
8. Conventional summerfallow

The following year all plots were sown to wheat with phosphate fertilizer seed placed at 30 kg/ha. No nitrogen fertilizer was applied.

Incorporation was done with a rotovator and a cultivator was used for subsequent weed control tillage. For the desiccation treatment Reglone was applied at 2.5 l/ha. The 2,4-D treatment was applied at a rate of 2 l/ha of a 500 formulation. The mustard snowtrap treatment consisted of planting 2 rows of mustard spaced 15 cm apart on 4 m centres. For the lentil snowtrap treatment, thirty cm wide strips of lentil were left standing every 4 m with the remainder incorporated.

Soil moisture determinations were made in late fall of the green manure year and again just prior to seeding of the wheat crop the following spring. Soil samples were taken in late fall and levels of available N and phosphate determined. Yield and quality of the succeeding wheat crop were determined.

Meteorological records on precipitation, minimum and maximum air temperatures were made at the Experimental Farm Metrological site. Annual precipitation was calculated on a crop year basis (Sept 1 of previous year to Aug 31 of current year) as it more closely reflected precipitation available for crop production than when done on a calendar year. Growing season precipitation was calculated as rainfall between May 1 and August 31.

Results and Discussion

Overwinter precipitation was much above normal for the winter of 1984-85, near normal for 1986-87 and much below normal for the other 3 winters. Overwinter precipitation is of importance as it can aid in recovery of moisture reserves used by the green manure crop. Growing season precipitation was above normal for 4 of 5 years and below normal in 1984-85, the year of above normal overwinter precipitation. Much of the growing season precipitation was received too late to be of maximum benefit to crops in 1987 and 1988. This was particularly true for crops grown on stubble.

Over the 5 year period, conditions were wetter than normal, but offsetting the good moisture conditions were above normal temperature early in the growing season, particularly in 1988.

Table 1. Precipitation at Scott for 5 - Twelve Month Periods 1984-1989.

12 month period	precipitation mm overwinter (Sept 1-Apr 30)	growing season (May 1-Aug 31)	12 month (Sept 1-Aug 31)
1984-85	270	178	448
1985-86	130	241	371
1986-87	157	308	465
1987-88	84	247	331
1988-89	116	231	347
Long term (75 yr)	153	200	353

While measuring aerial dry matter production was relatively easy, making accurate measurements on the roots was a much more formidable task due to their fragile nature. The methods used, provided an estimate of the weight of main roots only. No attempt was made to measure smaller roots that were broken in the excavation and cleaning process.

Where incorporation of the green manure was delayed to the full bloom stage, more than twice as much above ground dry matter was produced as where incorporation was done at the bud stage (table 2). Changes in root dry matter were smaller between the two stages of growth, but total dry matter was approximately doubled by later incorporation. Amounts of nitrogen returned to the soil increased from 38 to 75 kg/ha where incorporation was delayed.

Determinations of available N in the soil following the green manure and other crops were made in late fall. Available N levels were highest following summerfallow or a lentil green manure crop (table 3). Nitrogen levels were significantly lower where a pea or lentil grain crop was grown, but were lowest where a wheat crop was produced. Levels of available phosphate were not significantly affected by any of the treatments.

Fall soil moisture levels were highest for the summerfallow treatment and lowest for fertilized wheat. Soil moisture was reduced where the green manure crop was incorporated early, and declined further with late incorporation. Soil moisture levels generally tended to be even lower where a pea or lentil crop or a wheat crop without N fertilizer were grown but not as low as for fertilized wheat.

Soil moisture levels the following spring (table 3) were higher than the preceding fall for all treatments with highest levels recorded for the summerfallow treatment. However, the gain in soil moisture overwinter was substantially greater for all the cropped and green manure treatments than for summerfallow.

Table 2. Amounts of Dry Matter and Nitrogen Returned to the Soil by a Lentil Green Manure Crop Incorporated at 2 Stages of Growth (1984-88 avg)

	growth stage at incorporation	
	bud (early)	full bloom (late)
dry matter (kg/ha)		
- above ground	1570	3460
- roots	540	830
- total	2110	4290
Nitrogen returned (kg/ha)		
- above ground	34	68
- roots	4	7
- total	38	75

Table 3 Amounts of Nitrogen, Phosphate and Soil Moisture Levels Following Several Crops Including Lentil Green Manures (1984-88 avg.)

Preceding crop	Available nitrogen (kg/ha)	Available phosphate (kg/ha)	Soil moisture (mm) fall	spring
summerfallow	70	12	181	202
lentil green manure-early	66	13	165	191
lentil green manure-late	74	12	158	196
pea-grain	40	13	145	179
lentil-grain	44	12	152	178
wheat-no fertilizer N	30	14	140	169
wheat-fertilizer N @ 40 kg/ha	30	13	128	165
LSD (P=0.05)	8.9	n.s.	8.6	10.0

The following year, when wheat was grown, no fertilizer N was applied to any treatment except the one where wheat had been grown the previous year and was fertilized with N at 40 kg/ha. Wheat yields after the green manure treatments were not significantly different from summerfallow yields (table 4). Yields following a pea or lentil crop were reduced but not as much as where the preceding crop was wheat. Yields were lowest on wheat stubble where N fertilizer was not applied.

The treatments did not affect volume weight of the crop, however seed weight was affected. Seed weight tended to be lowest for wheat following wheat particularly where nitrogen was not applied. Protein content was high for all treatments but was highest where summerfallow and green manuring was practiced.

Soil N levels determined in late fall after harvest of the wheat crop did not reveal any significant residual treatment effects (data not shown).

Table 4. Yield, Volume Weight, Seed Weight and Protein Content of Wheat Grown Following Several Crops Including Lentil Green Manures (1985-89 avg.)

Preceding crop	yield (kg/ha)	vol. wt. (kg/hl)	seed wt. (g/1000K)	protein (%)
summerfallow	2340	74.4	29.1	17.0
lentil green manure-early	2360	74.0	28.3	17.2
lentil green manure-late	2250	74.0	29.0	17.0
pea (grain)	2110	74.7	28.9	16.5
lentil (grain)	2080	74.5	29.1	16.3
wheat-no fertilizer N	1610	73.4	27.3	16.3
wheat-fertilizer N@40kg	1830	74.4	28.0	16.6
LSD P = 0.05	108	n.s	0.56	0.29

Table 5. Yield, Volume Weight, Seed Weight and Protein Content of Barley Grown 2 years After Several Crops Including Lentil Green Manures (1986-89 avg. for 3 N application rates: 0, 40 and 80 kg/ha)

Preceding crop	yield (kg/ha)	volume wt. (kg/hl)	seed wt. (g)	protein (%)
summerfallow	2980	60.0	39.6	14.2
lentil green manure -early	3070	60.0	39.7	14.1
lentil green manure-late	2930	59.5	40.0	14.3
pea (grain	2790	60.3	39.3	13.8
lentil (grain)	2940	60.5	39.7	13.9
wheat-no fertilizer N	2920	60.2	40.2	14.0
wheat-fertilizer N@40 kg	2770	60.4	40.1	14.0
LSD P = 0.05	ns	ns	ns	ns

Yields of barley grown in year 3 after the wheat crop were not significantly affected by the year 1 treatments (table 5). Volume weights, seed weights and protein content of the barley crop were not significantly affected either.

In the second study where differing systems of managing the green manure crop were evaluated, levels of available soil phosphate were not affected (table 6). However, levels of available soil N were decreased substantially where the crop was harvested as seed or treated with 2,4-D to suppress growth. Where incorporation was done at the bud or full bloom stages, N levels were equal to summerfallow. Where strips of lentil were left standing or mustard strips were planted as snow trap after green manure incorporation or where the lentil was treated with a crop desiccant, N levels were intermediate.

Table 6. Amounts of available Phosphate and Nitrogen Following a Lentil Green Manure Crop with Several Management Practices at Scott (1988-89 avg).

Preceding green manure management practice	available nitrogen (kg/ha)	available phosphate (kg/ha)
incorporate at bud stage	72	17
incorporate at full bloom	88	14
desiccate at full bloom	54	16
2,4-D at full bloom	30	17
incorporate & mustard snowtrap	64	14
incorporate & lentil snowtrap	65	17
harvest as seed	32	17
conventional summerfallow	85	14
LSD P=0.05	15.1	ns

In fall after green manuring and seed harvest, soil moisture levels were greatest where conventional summerfallow practices were employed (table 7). Incorporating green manure at bud or full bloom, desiccation at full bloom or incorporation followed by growing mustard trap strips resulted in reduced fall soil moisture. Soil moisture levels were lowest where the lentil crop was harvested as seed, treated with 2,4-D at full bloom or incorporated and lentil trap strips were left to catch snow.

The three treatments where the soil surface was left relatively bare of vegetation, incorporation at late bud or full bloom, or conventional summerfallow resulted in net losses of moisture overwinter (Table 7). The two trap strip treatments gained the most moisture overwinter. Desiccating or treating with 2,4-D at full bloom or harvesting as seed also led to substantial gains in moisture overwinter.

At the time of seeding the succeeding wheat crop, soil moisture levels were similar for the treatments where snow trap strips were employed and for summerfallow. Other treatments generally tended to be lower. Again, where the lentil crop was harvested as seed or where 2,4-D was applied, soil moisture levels were lowest.

Grain yields were highest where trap strips were employed to catch snow (table 8). The treatment where lentil green manure was incorporated at full bloom and widely spaced rows of mustard were grown to trap snow provided the highest yields. Wheat yields were significantly higher for this treatment than for conventional summerfallow. Where the lentil crop was treated with 2,4-D a full bloom or harvested as seed, succeeding wheat yields were significantly lower than for summerfallow.

Table 7. Fall Soil Moisture After Green Manuring, Spring Soil Moisture Prior to Seeding a Wheat Crop and Overwinter Change in Soil Moisture with Several Green Manure Management Practices at Scott (1988-89 Avg.)

Preceding green manure management practice	Soil moisture (mm) fall	Soil moisture (mm) spring	Overwinter change (mm)
incorporate at bud stage	165	160	-5
incorporate at full bloom	155	153	-2
desiccate at full bloom	154	167	13
2,4-D at full bloom	127	149	22
incorporate & grow mustard trap strips	151	185	34
incorporate & leave lentil trap strips	132	175	43
harvest as seed	117	141	24
conventional summerfallow	191	172	-19
LSD P=-0.05	18.7	17.4	-

Table 8. Yield of Wheat Grown Following a Lentil Green Manure Crop with Several Management Practices (1988-89 avg.).

Preceding green manure management practice	yield (kg/ha)
incorporate at bud stage	1880
incorporate at full bloom	1760
desiccate at full bloom	1700
2,4-D at full bloom	1600
incorporate and grow mustard trap strips	2010
incorporate and leave lentil trap strips	1960
harvest as seed	1540
conventional summerfallow	1800
LSD P=0.05	191

Green manuring returned substantial quantities of dry matter and nitrogen to the soil. Accumulation of dry matter occurred rapidly between the bud and full bloom growth stages. For this reason it would be desirable to delay incorporation. The reduction in soil moisture due to delayed incorporation was surprisingly small and by seeding time the following spring soil moisture levels for the early and late incorporations were similar. Delayed incorporation did cause a slight reduction in succeeding wheat yields. Where incorporation was delayed to the full bloom stage, levels of available nitrogen were similar to earlier incorporation or to summerfallow. However, where the green manure crop was left standing overwinter, available nitrogen levels were reduced, suggesting a need for incorporation to speed mineralization.

At current fertilizer prices, the value of the nitrogen from the green manure crop was approximately $24 to $40 for early and late incorporation respectively. The value of that nitrogen can only be realized where it is utilized to replace fertilizer nitrogen in subsequent crop production. Results of the first study indicated that yields of wheat or barley grown 1 or 2 years after green manuring were not significantly affected. Data from the second study was limited but did suggest that yields of a succeeding wheat crop could be enhanced when snowtrapping was utilized following green manuring. Snow trapping appears to be an essential component of green manure management to recover soil moisture reserves.

Conclusions

- A lentil green manure crop returns from 2 to 4 tonnes/ha of dry matter and 40 to 75 kg/ha of N to the soil

- Delaying incorporation from late bud to full bloom stage of lentil growth approximately doubles amounts of dry matter and N returned.

- Snow trapping after green manuring enhances overwinter moisture recharge.

- Wheat yields after green manuring are equal to summerfallow yields in the absence of snowtrapping and may exceed summerfallow yields with snowtrapping.

- Green manuring did not affect a barley crop grown 2 years later.

- Pulse grain crops may be a preferred summerfallow substitute.

- Lentil green manures are feasible summerfallow substitutes if snowtrapping is employed. They may be best adapted to fields where conventional summerfallow does not result in adequate nitrogen mineralization.

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